§4. Long Pulse Operation of an 84 GHz Gyrotron (CPI) with a Depressed Collector and Transmission Line Test for LHD Experiment

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We have been developing an 84GHz CW gyrotron in collaboration with CPI as the power source in the ECRH system on LHD. The gyrotron (CPI #1R) has the capablity of depressed collector operation for the total output efficiency improvement, and reduction of input electric power and X-ray irradiation.

Firstly, the high power long pulse operation without the depressed collector was performed at NIFS testset(Nisshin power supply) of the plasma heating laboratory. The maximum performances obtained were 360kW/70msec, 230kW/250msec, 100kW/1.2sec, and 100kW/41.3% duty. The longest pulse widths for each power level were limited by outgases in the tube. The operation at this test set was stopped because of transferring the power supply to the heating device room of the LHD main building.

The substantial long pulse operation with the depressed collector was started at the heating device room by means of the power supplies manufactured by Toshiba Corporation. Main circuit of the gyrotron and the power supplies is shown in Fig.1. The power supplies consist of collector, body, anode, and heater power supplies. The collector power supply switches on and off the high power line by the GTO stacks. This power supply has no crowbar system. The surge current are blocked by the reactors, when arcings occur in the gyrotron. The body and anode power supplies are highly regulated and can be turned off within 10μsec. We added clamp diodes and resister between gyrotron body and collector to protect over voltage application on an insulating ceramic which was installed between gyrotron body and collector.

A typical oscilloscope trace of those voltages is shown in Fig. 2. These voltages are measured relatively to the cathode potential. When the collector voltage is firstly turned on up to 65kV by the GTO switch, the body voltage is pulled up to 65kV through the clamp diodes. After 5msec. later the body voltage is switched on up to 80kV. Finally the anode voltage is raised from -3kV to 25kV relative to the cathode, when the beam current starts to flow. In this case the current amounts to 10.5A. Then the collector voltage sags about 7kV, because the collector power supply is not regulated. The depression voltage increases from 15kV (=80kV-65kV) to 22kV (=80kV-65kV+7kV). No anode current increase was observed with such increase of the depression voltage and stable operation was retained.

Microwave power from the gyrotron was coupled to a corrugated waveguide with 88.9mm in diameter by a matching optics unit with 4 mirrors, and transmitted to the LHD vacuum vessel. Experimentally obtained transmission performances are summarized in Table 1. Total transmission efficiency was estimated to be 61%, including the coupling and transmission losses.

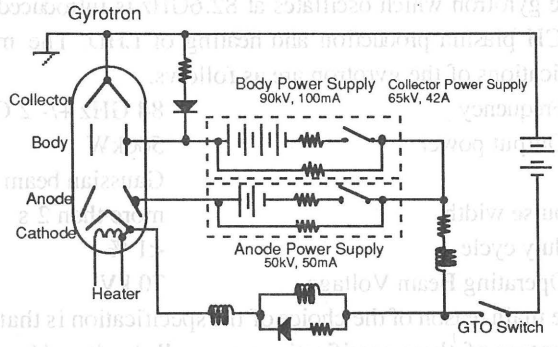

Figure 1 Main circuit of the gyrotron and the power supplies

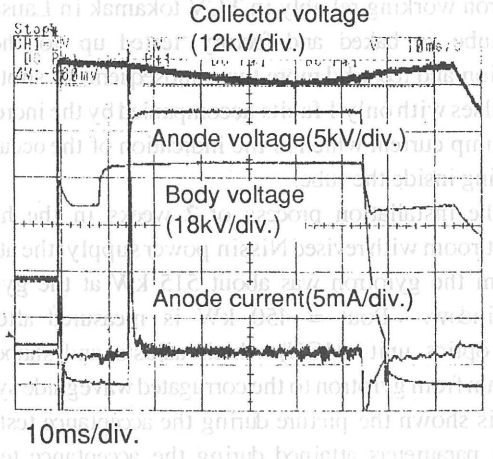

Figure 2 Typical oscilloscope traces of collector, body and anode voltages

Table 1 Results of high power RF transmission

	Gyrotron out	Dummy load	at LHD window
Transmission length	0	10 m	100 m
Components		4 mirrors in MOU 1 W/G switch 1miter bend	4 mirrors in MOU 1 W/G switch 2 polarizers 20 miter bends
Transmission efficiency	100%	76%	61%(estimated)
Achieved power & pulsewidth	380kW (estimated)	290kW, 30ms (measured)	236kW (estimated)
	200kW (estimated)	150kW, 0.2sec (measured)	120kW (estimated)
	151kW (estimated)	115kW, 0.5sec (measured)	92kW (estimated)
	132kW (estimated)	100kW, 0.1sec, 10% duty (measured)	80kW (estimated)